

Blockchain Technology and its effect on Environment: A Comparative Study between Proof-Of-Work and Proof-Of-Stake

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Abstract— With the growing interest in cryptocurrency and blockchain by renowned companies environmental issues are also being highlighted due to the exhaustion of huge amounts of energy. This paper aims to give a primary overview of how cryptocurrencies are created by using the proof of work method and how blockchain works. Statistical references have been given to elaborate on how this process consumes high energy and increases carbon footprint causing harm to the environment. In comparison, the proof of stake method has established itself as an eco-friendly alternative. Ethereum has already manifested that using PoS can resolve the problem and is also safe for the environment.

Keywords— Bitcoin, Blockchain, Cryptocurrency, Eco-friendly, Ethereum, Proof-of-Stake, Proof-of-Work

I. INTRODUCTION

China had the maximum percentage of computing power for mining Bitcoin which was approximately 75% of the world share in September 2019 (Cambridge Bitcoin Electricity Consumption Index (CBEI)). In May 2021, Beijing banned crypto mining in China due to environmental concerns. Statistics show that China is not the only country to take such major steps. There are numerous countries and provinces throughout the world that have either partially banned or put severe restrictions on crypto mining due to environmental concerns (Quiroz-Gutierrez). Another path-breaking decision on the same ground was taken by TESLA when Elon Musk revoked the acceptance of bitcoin for financial transactions in their company. Musk's announcement of accepting cryptocurrency for transactions had enraged some environmentalists previously. While banning bitcoin his tweet sounds comforting for them as he said that it is incorrect to burn huge amounts of fossil fuels

for creating bitcoin which will contribute negatively to climate change which is the prime concern of the whole world nowadays (BBC News). This paper provides an overview of what is a cryptocurrency, why it is creating a concern in environmental issues and climate change is the prime concern here, and what will be the eco-friendly alternative of crypto mining.

II. CRYPTOCURRENCY

Cryptocurrency is a currency that is used digitally or virtually and uses cryptography to secure its transactions. Cryptocurrencies use blockchain technology to maintain a secured ledger to record transactions on multiple computers. This makes it difficult for anyone to manipulate or alter the record of transactions.

Bitcoin is one of the first and most renowned cryptocurrencies. Satoshi Nakamoto created Bitcoin in

2009 (Nakamoto). Since then, numerous cryptocurrencies like Ethereum, Litecoin, and XRP have been created.

The main feature of cryptocurrencies is that they are operated through a decentralised platform, which means that they are not under any government or financial institution's control. This can be attractive to users who value privacy and autonomy. Cryptocurrencies also appeal to those who live in countries with unstable currencies or financial systems.

One of the main benefits of cryptocurrency is that it allows for secure, direct transfers without the need for a central authority. This can be especially useful for cross-border transactions, as it allows for faster and cheaper transfers than traditional methods.

However, there are also risks associated with cryptocurrency. Because a central authority does not regulate it, there is no recourse if something goes wrong. Cryptocurrencies are also highly volatile, meaning that their value can fluctuate significantly in a short period.

Though there are risks, there is a growth in the use of cryptocurrency. More and more businesses, including major retailers, are accepting cryptocurrency as payment. Some experts believe that cryptocurrency has the potential to revolutionise the way we think about and use money.

Overall, cryptocurrency is a complex and evolving field. It has the potential to bring significant benefits, but it is important to be aware of the risks and do thorough research before investing.

III. BLOCKCHAIN TECHNOLOGY

Blockchain technology is a digital ledger that is distributed over various nodes or computers and is decentralised in nature (Pilkington). Using this system transactions are recorded across many nodes. A number of transactions are grouped together and called a block which is secured cryptographically and then linked with the previous block to make a chain. Typically each block contains a nonce, a Merkle tree, a timestamp, a cryptographic hash of the previous block and the transaction data. Thus any alteration in a block can not be done without altering all the subsequent blocks and the consensus of the whole network.

The decentralised nature of blockchain technology means that it is not controlled by any single entity and is instead run by a network of computers that work

together to validate and record transactions. It is a secure and also transparent way of storing and transferring data and value.

Blockchain technology has many potential uses, including the ability to create and track supply chain networks, record financial transactions, and secure the exchange of sensitive information (Kadam). It has the potential to disrupt and transform a wide range of industries, including finance, healthcare, and government.

One of the most well-known and widely used applications of blockchain technology is the creation and use of cryptocurrency, such as Bitcoin. The use of blockchain technology in the creation of cryptocurrency helps to ensure the security and transparency of transactions.

Overall, blockchain technology has the potential to revolutionise the way that we store, transfer, and verify data and value. It is a powerful tool that has the potential to transform a wide range of industries and applications.

IV. PROOF OF WORK

Proof of Work (PoW) is a consensus algorithm (Nakamoto) used by many cryptocurrencies, including Bitcoin, to secure their networks and validate transactions. The process of PoW involves miners competing to solve complex mathematical puzzles in order to add a new block of transactions to the blockchain. The miner who solves the puzzle first is rewarded with a certain number of coins, as well as the transaction fees associated with the transactions included in the block (Buterin).

Here is an overview of the process:

- A new block of transactions is broadcast to the network.
- Miners take the data in the block, along with a nonce (a random number), and apply a hashing algorithm to it. The resulting hash must meet certain criteria, such as starting with a certain number of zeroes.
- Miners repeatedly increment the nonce and re-hash the data until a hash is found that meets the criteria. This process is called "mining" and also called "finding a block".
- The miner who finds the valid hash broadcasts the block to the rest of the network, and other

nodes on the network check the validity of the block by running the hash function on the block's data and ensuring that the result is the same as the hash the miner found.

- If the block is determined to be valid, it is added to the blockchain, and the miner who found the block is rewarded with coins.
- The process then repeats with a new block.

It's important to note that the difficulty of the puzzle is adjusted by the network to ensure that new blocks are added at a steady rate, regardless of the total computational power of the miners on the network. Additionally, because the puzzle is very difficult to solve but easy to verify once solved, it's practically impossible for a miner to cheat by adding a block to the blockchain without having actually solved the puzzle. This helps ensure the security and integrity of the blockchain.

An important feature of PoW is that it requires a significant amount of computational power which is known as the "mining power" or "hashrate" which makes the network more secure and resistant to 51% attack or double spend attack.

V. ENERGY CONSUMPTION IN MINING:

Mining cryptocurrencies using the Proof of Work (PoW) algorithm can be a very energy-intensive process. This is because miners need to run powerful computer systems with high-performance processors in order to solve the complex mathematical puzzles required by the PoW algorithm. The hardware of these systems consumes a large amount of electricity to run, and this consumption can be a significant cost for miners.

The total energy consumption of the Bitcoin network, for example, has been estimated to be on the order of tens of gigawatts. This is roughly equivalent to the energy consumption of a small country, and it continues to grow as more miners join the network and the difficulty of the puzzles increases.

It's important to note that the energy consumption is directly proportional to the hash rate of the network, which means that more miners and more powerful machines result in more energy consumption.

Energy consumption has sparked concerns about the environmental impact of cryptocurrency mining. The electricity used for mining primarily comes from fossil fuels, which means that mining operations can

contribute to greenhouse gas emissions and climate change. Additionally, the high energy consumption of mining can lead to local power shortages and increased electricity costs for everyone.

To compare, gold mining typically releases about 21.7 kg CO₂-e/t ore or about 11.5 t CO₂-e/kg Au(Mudd) whereas bitcoin releases 44.07 Mt CO₂ annually ("Bitcoin Energy Consumption Index").

Overall, it's important to consider the energy consumption of mining when evaluating the sustainability of different cryptocurrencies and their underlying technology.

VI. ENVIRONMENTAL CONCERN:

The environmental impact of crypto mining is a serious concern as it uses the proof of work method which needs a huge amount of energy that comes from burning fossil fuels and increases the carbon footprint. This problem has been addressed by a number of researchers which will be reviewed now. In the year 2014, O'Dwyer and Malone investigated the energy consumption for mining Bitcoin and found that energy consumed by Bitcoin was comparable to the amount of electricity consumed by Ireland at that time. Krause and Tolaymat showed in their comparative study that even most of the mineral mining consumed lesser energy than the cryptocurrency mining activities to maintain a similar market value and also calculated the amount of CO₂ emission with great importance. In the research of Jones et al. the concept of Bitcoin as "digital gold" has been degraded to the status of "digital crude" and to establish this they elaborated their findings of Bitcoin mining for 2016 to 2021 from three different economic perspectives. Firstly, the per coin climate damages due to Bitcoin mining kept increasing with industry maturation which was not expected. Secondly, climate damages due to mining are more expensive sometimes than the price of each Bitcoin if measured economically. Thirdly, CO₂ emission due to Bitcoin mining is significant if measured in comparison with electricity generation by source, crude oil processing, automobile manufacturing, agricultural meat production and precious metals mining. Gellersdörfer et al. experimented with more than 500 types of mineable crypto coins and tokens and reached the conclusion that all of them only together consume only one-third of the total energy consumption while Bitcoin alone consumes the majority, i.e., two third of the total energy consumption which is noteworthy.

In order to overcome the problem of huge energy consumption and CO₂ emission the Proof of Stake method has been gaining popularity and cryptocurrencies like Ethereum have already changed their process of creation from PoW to PoS method ("Ethereum Upgrades (Formerly 'Eth2')").

VII. PROOF OF STAKE

Proof of Stake (PoS) is a consensus mechanism used to secure a blockchain network. Unlike Proof of Work (PoW) systems, where miners solve complex mathematical puzzles to validate transactions and create new blocks, in PoS systems, validators (often referred to as "stakers") are chosen to create new blocks based on the number of coins they hold and are willing to "stake" (i.e., lock up) as collateral (Arslan et al.).

Here's the process of PoS in detail:

Stakers, who hold and lock up a certain amount of the blockchain's native cryptocurrency, are chosen to validate transactions and create new blocks. The more coins a staker holds and locks up, the higher the likelihood they will be chosen to create a new block.

When a new block is created, the staker who created it is rewarded with a certain amount of the blockchain's native cryptocurrency. This incentivizes users to hold and stake their coins, as they can earn a return on their investment.

To ensure network security, PoS systems often implement a system of penalties for malicious stakers. For example, if a staker is found to be creating invalid blocks, they can be penalised by having their staked coins confiscated.

PoS also uses randomization in selecting the creator of the next block, this is called "randomised block selection" or "slot leader" which ensures that a single entity or group of entities cannot control the block creation and manipulate the blockchain.

PoS is considered to be more energy efficient than PoW as it does not require computational power to solve complex mathematical puzzles, it only requires holding and locking the coins.

Overall, the Proof of Stake mechanism provides a way to secure a blockchain network through a process of staking and validating transactions, rather than through mining. It is also more energy efficient as it does not require computational power to validate transactions.

VIII. PoS ENERGY CONSUMPTION

Because PoS does not require the same level of computational power as PoW, it is often considered to be more energy efficient. Instead of requiring miners to perform complex calculations, PoS only requires validators to hold and lock up a certain amount of the network's native cryptocurrency, and as a result, it uses less electricity. This means that the energy consumption is much lower in PoS, as compared to PoW.

In summary, PoS uses less energy than PoW because it does not require miners to perform complex mathematical calculations to validate transactions and add new blocks, instead it uses validators who hold a stake in the network to validate transactions and add new blocks, which is less energy intensive.

IX. ETHEREUM NETWORK

The Ethereum network is an open-source, decentralised blockchain platform that enables the creation of smart contracts and decentralised applications (dApps). It was created in 2015 by Vitalik Buterin, a programmer and co-founder of Bitcoin Magazine.

One of the key features of the Ethereum network is its support for smart contracts. Smart contracts are self-executing contracts with the terms of the agreement written directly into code. They can be used to automate various processes, such as the transfer of assets or the execution of financial transactions.

The Ethereum network is powered by its native cryptocurrency, Ether (ETH). Ether is used to pay for transactions and computational services on the network, and is also used as a form of payment for developers building on the Ethereum platform.

The Ethereum network uses a consensus mechanism called Proof of Stake (PoS) to validate transactions and create new blocks. In PoS, validators (stakers) are chosen to create new blocks based on the number of coins they hold and are willing to "stake" as collateral. This is designed to be more energy efficient than the Proof of Work (PoW) mechanism used by Bitcoin.

The Ethereum network also has a built-in programming language, called Solidity, that (Ethereum)developers can use to write smart contracts and dApps. This language is similar to JavaScript and is designed to be easy to learn and use.

Ethereum also has a decentralised virtual machine called the Ethereum Virtual Machine (EVM) that executes smart contracts. It allows smart contracts to be executed independently, without the need for a central authority.

One of the most popular use cases for the Ethereum network is the creation of Initial Coin Offerings (ICOs). An ICO is a fundraising mechanism in which a new cryptocurrency project sells a portion of its tokens to early supporters in exchange for investment.

Overall, The Ethereum network is a decentralised platform that enables the creation of smart contracts and decentralised applications and is powered by its native cryptocurrency, Ether (ETH). The network uses a Proof of Stake (PoS) mechanism to validate transactions and create new blocks and has a built-in programming language, Solidity, that developers can use to write smart contracts and dApps.

The Ethereum network started upgrading from PoW to PoS to make the network more secure, scalable and sustainable. The Beacon Chain started on December 1, 2020. It was merged with the Ethereum mainnet on September 15, 2022. Sharding is expected to happen anytime between 2023 to 2024 ("Ethereum Upgrades (Formerly 'Eth2')").

X. ETHEREUM AS AN ENVIRONMENT-FRIENDLY ALTERNATIVE

Since its move towards PoS from PoW Ethereum network is proving to be a great alternative as a blockchain that is much more energy-saving.

A report (Ethereum) has shown the statistics that after shifting to the Proof-of-Stake method from the Proof-of-Work method, Ethereum has reduced its annual energy consumption to 2.601 MWh across the entire global network which has also reduced its yearly carbon emission to approximately 870 tonnes of CO₂e as a result which is remarkably low. It sounds astonishing that the energy consumption of Bitcoin is 100TWh/yr which is 38000 times more than that of Ethereum. Not only that, Ethereum previously used 78 TWh/yr energy while using the Proof-of-Work method which is 30000 times higher than the power consumption of Ethereum using the Proof-of-Stake method.

XI. CONCLUSION

With the growing process of digitalisation, Cryptocurrency is creating a self-sufficient parallel financial world in the 21st century. As we know that great responsibility comes with great power, We must consider the environmental phenomena very seriously. Immense energy consumption and CO₂ emission are the major issues here. It is desired that the cryptocurrency must be sustainable as well as scalable and secure. The PoS method is tested by the Ethereum network to be more scalable, secure and above all much more sustainable. Considering the environmental concern it is expected that all the cryptocurrencies and blockchain networks will switch to more sustainable methods of block validation.

REFERENCES

- [1] Arslan, Caglar, et al. "Comparative Analysis and Modern Applications of PoW, PoS, PPoS Blockchain Consensus Mechanisms and New Distributed Ledger Technologies." *Advances in Science, Technology and Engineering Systems Journal*, vol. 6, no. 5, Advances in Science, Technology and Engineering Systems Journal (ASTESJ), Oct. 2021, pp. 279–90, doi:10.25046/aj060531.
- [2] BBC News. "Tesla Will No Longer Accept Bitcoin Over Climate Concerns, Says Musk." *BBC News*, 13 May 2021, www.bbc.com/news/business-57096305. Accessed 15 Jan. 2023.
- [3] "Bitcoin Energy Consumption Index." *Digiconomist*, 6 Dec. 2022, digiconomist.net/bitcoin-energy-consumption. Accessed 9 Jan. 2023.
- [4] Buterin, Vitalik. "Ethereum Whitepaper." *ethereum.org*, 2014, ethereum.org/en/whitepaper. Accessed 3 Jan. 2023.
- [5] *Cambridge Bitcoin Electricity Consumption Index (CBECI)*. ccaf.io:443/cbeci/mining_map. Accessed 15 Jan. 2023.
- [6] "CCRI Industry Report." *CCRI - Crypto Carbon Rating Institute*, CCRI - Crypto Carbon Rating Institute, Sept. 2022, carbon-ratings.com/dl/eth-report-2022. Accessed 4 Jan. 2023.
- [7] Ethereum. "Ethereum Energy Consumption." *ethereum.org*, ethereum.org/en/energy-consumption.
- [8] "Ethereum Upgrades (Formerly 'Eth2')." *ethereum.org*, ethereum.org/en/upgrades.
- [9] Gallersdörfer, Ulrich, et al. "Energy Consumption of Cryptocurrencies Beyond Bitcoin." *Joule*, vol. 4, no. 9, Elsevier BV, Sept. 2020, pp. 1843–46, doi:10.1016/j.joule.2020.07.013.
- [10] Jones, Benjamin A., et al. "Economic Estimation of Bitcoin Mining's Climate Damages Demonstrates Closer Resemblance to Digital Crude Than Digital Gold." *Scientific Reports*, vol. 12, no. 1, Springer Science and Business Media LLC, Sept. 2022, doi:10.1038/s41598-022-18686-8.

- [11] Kadam, Suvarna. "Review of Distributed Ledgers: The Technological Advances Behind Cryptocurrency." *International Conference Advances in Computer Technology and Management (ICACTM)*, 2018, www.researchgate.net/publication/323628539_Review_of_Distributed_Ledgers_The_technological_Advances_behind_cryptocurrency#:~:text=Blockchain%20and%20related%20Distributed%20Ledger,financial%20and%20real%20Desta%20te%20assets.
- [12] Krause, Max J., and Thabet Tolaymat. "Quantification of Energy and Carbon Costs for Mining Cryptocurrencies." *Nature Sustainability*, vol. 1, no. 11, Springer Science and Business Media LLC, Nov. 2018, pp. 711–18, doi:10.1038/s41893-018-0152-7.
- [13] Mudd, Gavin M. "Global Trends in Gold Mining: Towards Quantifying Environmental and Resource Sustainability." *Resources Policy*, vol. 32, no. 1–2, Elsevier BV, Mar. 2007, pp. 42–56, doi:10.1016/j.resourpol.2007.05.002.
- [14] Nakamoto, Satoshi. "Bitcoin: A Peer-to-Peer Electronic Cash System." *Bitcoin*, bitcoin.org/bitcoin.pdf. Accessed 3 Jan. 2023.
- [15] O'Dwyer, K. J., and D. Malone. "Bitcoin Mining and Its Energy Footprint." *25th IET Irish Signals & Systems Conference 2014 and 2014 China-Ireland International Conference on Information and Communities Technologies (ISSC 2014/CICT 2014)*, Institution of Engineering and Technology, 2014, doi:10.1049/cp.2014.0699.
- [16] Pilkington, Marc. "Blockchain Technology: Principles and Applications." *Research Handbook on Digital Transformations*, Edward Elgar Publishing, Sept. 2016, pp. 225–53, doi:10.4337/9781784717766.00019.
- [17] Quiroz-Gutierrez, Marco. "Crypto Is Fully Banned in China and 8 Other Countries." *Fortune*, 5 Jan. 2022, fortune.com/2022/01/04/crypto-banned-china-other-countries. Accessed 15 Jan. 2023.